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A Model Proposal for Long-Lasting Electromagnetic Forces-Biological System Interaction: Molecular Fatigue Damages

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Abstract

None of the known interaction models of electric and magnetic fields with the biological system can completely explain the effects which occur as a result of long-lasting exposure to electric and magnetic fields.

We think that effects which cannot be explained by exposure to long-lasting, and albeit very low, electro-magnetic effects arise from molecular fatigue and the damage accumulation which occurs as a result of it.

Molecular fatigue is similar to the phenomenon which is observed in isotropic bodies (metals) and is defined as metal fatigue. Metal fatigue causes emergence of invisible capillary vessels in the material if loads and forces affect the material periodically by changing directions and if this effect is repeated many times. Fracture may occur even in stress values which are far below the tensile stress and shear stress, the reason behind this is molecular fatigue.

Molecular fatigue may emerge in anisotropic systems like bones and more complex systems in the human body such as cartilage, muscle much the same with isotropic bodies. Because biological system is a system which is exposed to constantly moving and repeating forces as well. These forces and gravitational forces act like a potential source by creating pressure electrification in the system and enable molecular production in these tissues. However, when the effects exceed certain values and durations, molecular fatigue occurs and brings about negative consequences in the live system with the emergence molecular fatigue damage accumulation in structures such as bones, muscles, cardiac muscles, receptors, ion channels.

Keywords: Long-lasting electromagnetic forces; Biological interaction; Molecular fatigue

General Information

Known interaction models of electric and magnetic fields with the biological system are as follows [1,2]

1 - Effects on cell surface structures.
2 - Polarization Forces.
3 - Coulombic Forces.
4 - Effects of the loads induced on cells.
5 - Surface loads induced on cell matrix and substrant.
6 - Cyclotron resonance and ion parametric resonance.
7 - Lednev model.
8 - Biologic electron transfer.
9 - Effects on free radical reactions.

None of interaction models can completely explain the effects which occur as a result of long-lasting exposure to electric and magnetic fields.

Many laboratory studies and epidemiological studies have reported that Electromagnetic fields cause serious health problems. One is exposed to electric and magnetic fields from high-tension lines, all kinds of electrical appliances used at homes and in industry, earth's magnetic field and medical devices such as Magnetic resonance [3].

In further in vitro experiments, Zhao, *et al.* found that application of physiological Direct current Electromagnetic field directed movement of bone cells and other cell types. This phenomenon is called electrotaxis or galvanotaxis [4].

EMF (Electromagnetic field) frequencies in the body are normally in the range of extremely low frequencies (ELF). These EMF include the action potentials of nerves and heart tissue, skeletal muscle vibrations and frequencies elicited by rhythmic activities within other body tissues. Thus, we concentrate on these frequencies in the present review [5].

A current survey of the literature reveals many recent advances in our understanding of EMF, especially DC EF. Today we are experiencing a revolution because many cell biological findings are now explainable by ion dynamics (Ca^{2+}, H^+ and related ion pumps and voltage sensors) and their action on small signaling molecules. This clearly is a novel link to classical findings in molecular and cell biology. A number of insightful studies by groups including those of McCaig and Adams directly couple EMF to cell biology [4,6,7]. Levin demonstrated that DC EF produced by ion Channels (especially for H^+, K^+ and Ca^{2+}) provide specific signals that regulate cell behavior during embryonic development, normal tissue turnover and regenerative repair [8]. Thus far, roles have been proposed for endogenous currents (EF, ion currents and secondary distribution of small molecule in polarizing cells; patterning embryos during gastrulation, neurulation and organogenesis; directing transport of maternal components in insect oocytes; neural differentiation; guiding migration of many vertebrate cell types; Xenopus tail regeneration [9-13].

The most important candidate is ion movement (e.g. by voltage-sensitive Ca^{2+} channels) [14]. However, in the case of K^+ dependent signaling, Ca^{2+} fluxes were not affected by K^+ channel activity. Levin reports that in some studies, cell biological effects seem to depend on the particular transporter involved, indicating that the type of ion and perhaps its movement dynamics also act as signals [8,15].

An additional effect for enhancing sensitivity (already addressed in the present review) was also discussed by Kindzelskii and Petty: the coherence and cooperative interaction of receptors to receptors or channels to channels (the distance of individual channels being only about 7 nm) [16]. The coupling may take place via conformational mechanisms or via other coupling (electron tunneling or other quantum effects). All these mechanisms may further improve the sinyal amplification [16,17].

Berenice Noriega-Lunaa, *et al*, have seen that few studies report the influence of electromagnetic fields on cell structure [18]. Thus, the objective of this study was to evaluate the impact of a pulsed magnetic field of 0.70mswidth, intensity of 0.65mT and frequency of 4Hz on the structure of osteoblasts (cell line MG-63), in early stages of cell growth and in short periods of exposure. The systematic evaluation of this effect was performed by analysis of cell density, pattern of protein and microfibril distribution of F-actin and -tubulin and nuclear structure [18].

In recent studies, electromagnetic fields have been claimed to change dual interactions between nervous system, hormones and immune system. Their effect on DNA, RNA, protein synthesis, cell division, cell surface features, ion entry-exit from the cell membrane such as Ca, Na, ion bonding, signal transmission (neurotransmitters, hormones, enzymes), ion transport and activation of some enzymes have been researched [19-21]. With the impact of electromagnetic fields, atoms and molecules of the body may lose the electrical balance they established between each other, biochemical activities may get affected, electrical structure in the communication of cells and tissues may break down [22,23].

With ELF MF, immunity may deteriorate the impact on the functioning of immune system cells and tumor phenomena are claimed to become more frequent [24,25]. Other child cancers and mainly child leukemia, adult cancers, depression, suicide cases, cardiovascular diseases, reproduction disfunctions, developmental anomalies, immunological modifications, neurobehavioural effects and neurodegenerative diseases increase compared to normal population [26-28].

Long-lasting interaction consequences of ELF EMF can be evaluated under three main headings as cancer cases, cardiac results and diabetes according to experimental and epidemiological studies [26-29].

Average 2-2.25% of child leukemias in the world have been reported to arise from electromagnetic fields at home. This values is twice the amount of the normal population30. Approximately 10-15% of cancer cases have been found to be related to EM fields with 0-300 frequency [30].

Fields with Hz frequency exposed in everyday life have been demonstrated to increase brain tumors, leukemia and acute myeloid leukemia in men. Many epidemiological studies have demonstrated increased cancer incidence in residents living in the vicinity of high-tension lines or workers of these areas as well [31-35].

Savitz, *et al*, have researched the CV disease mortality related to occupational magnetic field in 140000 electricity workers. They have observed high mortality due to arrhythmia and acute myocardial infarction in workers who were exposed to high magnetic field for a longer period of time [36].

In the studies carried out in electricity workers in Sweden and Italy, it has been stated that low magnetic fields present no cardiovascular risk [37]. However, according to the findings of Savitz, deaths as a result of myocardial infarction and arrhythmia are possible with long-term μT level exposure [36].

In wide prospective cohort studies, it is accepted that heart disease will be increase in the next few years with change of HRV is [38-41].

In recent years, exposure to ELF EM fields has been accepted to trigger a certain diabetes type defined as Type III diabetes (Brittle Diabetes). According to this study, blood glucose level rises momentarily when approaching electromagnetic fields and returns to its normal values when withdrawn [42]. Nevertheless, Type II Diabetes may occur with very long-lasting exposure. According to this, one of the causes of ever-increasing Diabetes disease in the world population could be these fields. Such studies are being carried out.

We think that effects which cannot be explained by exposure to long-lasting, and albeit very low, electro-magnetic effects arise from molecular fatigue and the damage accumulation which occurs as a result of it.

Molecular fatigue: Molecular fatigue is similar to the phenomenon which is observed in isotropic bodies (metals) and is defined as metal fatigue [43]. Metal fatigue causes emergence of invisible capillary vessels in the material if loads and forces affect the material periodically by changing directions and if this effect is repeated many times [43]. Materials fatigue failure or damage has a molecular origin. It must be also taken into account that the mechanisms of damage under cyclic loading (fatigue conditions) may be different depending on material type (metals, ceramics, polymers, composites, biological tissue).

For this reason, the changes provoked by mechanical loading in the microstructure of materials (in particular, living tissues) need to be investigated.

As the periodic number and effect of the applied load increase, capillary cracks start to grow and material can sometimes fracture even as a result of a small force. Endurance of the strained material decreases with repeated cyclical load applications. Fracture may occur even in stress values which are far below the tensile stress and shear stress, the reason behind this is molecular fatigue [43,44]. Fatigue is a phenomenon which occurs not under static loads but dynamic loads [43,44].

Molecular fatigue may emerge in anisotropic systems like bones and more complex systems in the human body such as cartilage, muscle much the same with isotropic bodies. Because biological system is a system which is exposed to constantly moving and repeating forces as well. These forces and gravitational forces act like a potential source by creating pressure electrification in the system and enables molecular production in these tissues [45,46].

However, when the effects exceed certain values and durations, molecular fatigue occur and brings about negative consequences in the live system with the emergence molecular fatigue damage accumulation in structures such as bones, muscles, cardiac muscles, receptors, ion channels [45,46].

Repetitive exposure to low density loadings for short periods causes low-level stress in the cortical bone and creates damage on microstructural level. However these repetitive motions in the bone tissure are of a potential stimulant nature in bone formation. Bone formation which occurs as in vivo may repair the damage which occurs in low-density loadings such as walking [45,46].

Muscle fatigue is defined as the loss of maximum strength and force output [47].

Recent studies have focused on understanding the fundamental mechanisms of muscle contraction and how partial fatigue factors distort contraction functions. Fatigue in running a marathon and other durability activities could be related to musle glycogen consumption, low blood glucose or dehydration [47,48].

Cellular aspect of muscle fatigue is important. Factors which cause cellular muscle fatigue are considered as changes in stimulation contraction duality, ionic changes, distortions in cell metabolism, changes in cell ultrastructure. Out of these factors, stimulation contraction duality and changes in cell metabolism are most accentuated [47].

Many diseases are associated with ion entry and exit into cell. Ion flow occurs through ion channels. Ion channels are in the structure of macromolecular protein. These molecular structures work normal in their natural process, this work occurs by the interaction with another molecule. However, when these molecular structures are exposed to any external force long term as ELF EMF, their folding functions will be disrupted, cannot distribute the power falling on them and the molecule may lose its function in time. For example, muscle fatigue is known as increase in the time of Ca^{+2} transitions, Ca channels move slowly so relaxation time is extended [49-51]. Other reason of muscle fatigue is insufficient Na-K pump activity, and this is the pump protein [52]. As is seen, basis of fatigue at macro structures as muscle is the molecular fatigue and if it continues for a long time, dysfunctions may occur.

Diabetes, cancer and cardiac diseases depend on many reasons and they occur by long-term effects. Nowadays, there is great increase in the population of such diseases with growing environmental factors. Environmental ELF- EMF is one of these factors and these are available in many literatures given below.

In the increase of these diseases, by long-term exposure to ELF-EMF and functional deceleration and disorder by fatigue and occurrence of defects in molecule may possible. Piezzoelectrification in living bone tissue increases the collagen synthesis and bone tissue ranges normally, but extreme periodic loads cause molecular fatigue and capillary cracks in time [53]. ELF-EMF affects all cell membranes in general. Complex cell membranes detect and amplify poor electrical and chemical signals [54]. In order to make changes in cell, external EMF is not required to be penetrated into cell. By effecting signal transduction pathways, it may regulate cell proliferation and differentiation. ELF EMF can cause the initiation of disease process without being penetrated to cell membrane

by anyway and even can provide transformation to a cancer phenotype [55]. Goldman, *et al*. showed that EMF effects Ca flow at cell membrane. In vitro experiments made in human tissues, they observed that ELF EMF had increased Ca flow [56]. Liburdy, *et al*. showed that ELF EMF had made it by opening CA channels rather than increasing Ca mobilization from endoplasmic reticulum [57]. Due to fact that it controls signal transduction, cell division, cell differentiation and cell proliferation, signal transmission exchange induced by EMF has a strong potential at tumor formation and promotion. Ca flow, which was induced by the exposition to EMF, causes the change and immunosuppression of T lymphocytes and other immune system factors. Changes in cellular Ca flow stimulate a group of enzyme which is called as protein kinases that play role in regulating various cell functions. Protein kinase activity is associated with cancer [58].

Cardiac activities completely depend on Na, K, Ca flow in cell membrane. It was shown in several studies that transition of these ions had been affected by EMP exposure. And it shows that channel proteins providing transmission of these ions were affected, and it is likely that cardiac diseases may occur by the formation of molecular fatigue in these molecular structures by long term EMF exposure [59]. However, cardiac diseases occur after the exposure of these areas for 5-6 years and cancer occurs after the exposure of these areas for 10-15 years [60]. So, it is difficult to make such long-term experimental studies and show molecular fatigue. However, according to current literature information, it is very likely that these diseases are associated with the molecular fatigue induced by EMF.

Conclusion

We think that similar to metal fatigue which occurs in isotropic bodies with constant dynamic forces, long-lasting electromagnetic effects cause disease and deaths by creating molecular fatigue and related damage accumulations in the live system.

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